

Meteor Detection during 2011-Leonid Meteor Shower using Indian MST Radar

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Abstract- The Leonid meteor shower on 17th and 18th November 2011 was observed widely for showers using Indian MST Radar . Data was collected from vertical, East20, West20, North13 beams. The Sporadic E (Es) echoes were received frequently from the northward beam, and these echoes spread over many range bins. The method of detection of Meteor based on SNR threshold after denoising was employed. Even long Echoes were observed with a period of 3 seconds. The results shows that the very faint meteors can be detected by denoising with appropriate wavelet (here Db5) chosen.

Keywords – Discrete Wavelet Transform (DWT), Signal Denoising, wavelet thresholding

I. INTRODUCTION

wavelets have been found to be a powerful tool for removing noise from a variety of signals (denoising). They allow to analyse the noise level separately at each wavelet scale and to adapt the denoising algorithm accordingly. Wavelet thresholding methods for noise removal, in which the wavelet coefficients are thresholded in order to remove their noisy part, were first introduced by Donoho in 1993. The theoretical justifications and arguments in their favour are highly compelling. These methods do not require any particular assumptions about the nature of the signal, permits discontinuities and spatial variation in the signal, and exploits the spatially adaptive multiresolution of the wavelet transform. The detection of faint meteor echoes were not proportionate with the existing methods and this paper presents the even detection of faint Meteors using wavelet based denoising.

II. OBSERVATIONS

The Indian MST radar was operated in meteor mode to observe Leonid meteor shower echoes from 17th –18th November 2011 between 18:00–06:00 LT The technical details of the radar system are given by Rao et al. (1995). To make a truly representative measurement of the meteor occurrence rate, the volume of the atmosphere probed by the radar should be larger. This demands a large width for the radar beam. In order to infer the height of the meteor echo reliably from the measured slant range, and the zenith angle of the radar beam, it is necessary to have a narrow radar beam. In this experiment, data were collected alternately with the EW sub arrays both oriented at a 20° zenith angle towards west or east and N sub-array oriented at a 13° zenith angle towards north, depending on the array chosen. Sporadic E (Es) echoes were received frequently from the northward beam, and these echoes spread over many range bins. One frame of data was obtained with the northward, one with eastward, one with westward and one with zenith ward beam and this sequence was repeated. Thus, successive sets of data frames of 4 each contained one from the northward beam, westward beam, eastward beam and zenith beam. The radar parameters were selected such that the Pulse Repetition Frequency (PRF) was 1000 Hz, with a pulse width of 8μs.

Each data frame had 34 range bins at 1.2 km range intervals from 79.95 km to 120 km. Four successive Inphase (I) and Quadrature (Q) samples for each range bin were coherently averaged, making the effective sampling interval of

4 ms. Each data frame had continuous data for 4.09sec similar to that employed by Raghava Reddi and Nair (1994). The system required a set-up time of a few seconds for each frame, and so the successive data frames are not continuous in time. The peak power radiated by the four sub-arrays was about 480kW, which is large enough to deem the system powerful for meteor patrolling. The data were processed off-line to separate the frames containing signatures of meteor echoes.

III. WAVELET TRANSFORM

The wavelet Transform is a very useful tool in the analysis of non-stationary signals such as Radar signal. The Discrete wavelet transform is based on the concept of MultiResolution analysis (MRA), a signal is decomposed into a sum of details and approximations at different levels of resolution, as shown in below block

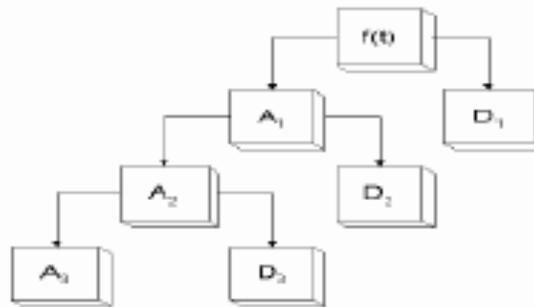


Fig. 1. Decomposition tree of a signal $f(t)$, D_i and A_i are the details and approximations at level i

The details represent the high-frequency components. While the approximations represent the low-frequency components of the signal. The decomposition algorithm is fully recursive.

At each stage of the MRA the signal is passed through a high-pass filter (called the scaling filter), denoted as G and a low-pass filter (called the wavelet filter), denoted as H . These filters are quadrature mirror filters that satisfy the orthogonality conditions $HG^* = GH^* = 0$ and $H^*H + G^*G = I$, where I is the Identity matrix. The filters H and G are the decomposition filters while H^* and G^* are the reconstruction filters. The coefficients of H and G depend on the particular wavelet used for the decomposition.

IV. METHOD OF ANALYSIS

In this paper Discrete Wavelet analysis is used instead of the continuous wavelet analysis. Using the wavelet analysis to denoise signals seems to be better than the traditional low pass filtering. In fact, because amplitude denoising is performed instead of frequency denoising, the low frequency noise can also be suppressed.

To denoise a signal with wavelet transforms, the detail coefficients are thresholded. Either soft thresholding or hard thresholding can be applied for a signal. Here for the MST Radar signal soft thresholding was used.

With the data received from the Indian MST Radar in Inphase (I) and Quadrature (Q) for each frame, the DC component was removed by the use of Hilbert transform, then Signal to Noise Ratio was calculated based on Hildebrand and Sekhon (1974) for each data frame containing 34 range bins and denoising was done with the use of Db5 wavelet for decomposition level "1" and by using Rigrsure threshold method. Signal to Noise Ratio was calculated once again after denoising and a comparison was made without denoising SNR. Meteors can be detected by setting the SNR greater than 0dB for a range bin. The advantage of denoising is that whenever a weak meteor occurs it can be detected efficiently.

V. RESULTS

When the echo in one or more range bins exceeded a Signal to Noise Ratio (SNR) of a specific threshold (0dB), then the frame is identified to contain backscattered echo from the meteor trails and is subsequently archived. Multiple Meteor Echoes were detected and few were shown in below figures (fig.2-fig.9) as shown below. A very faint Meteor was observed in figure 3.

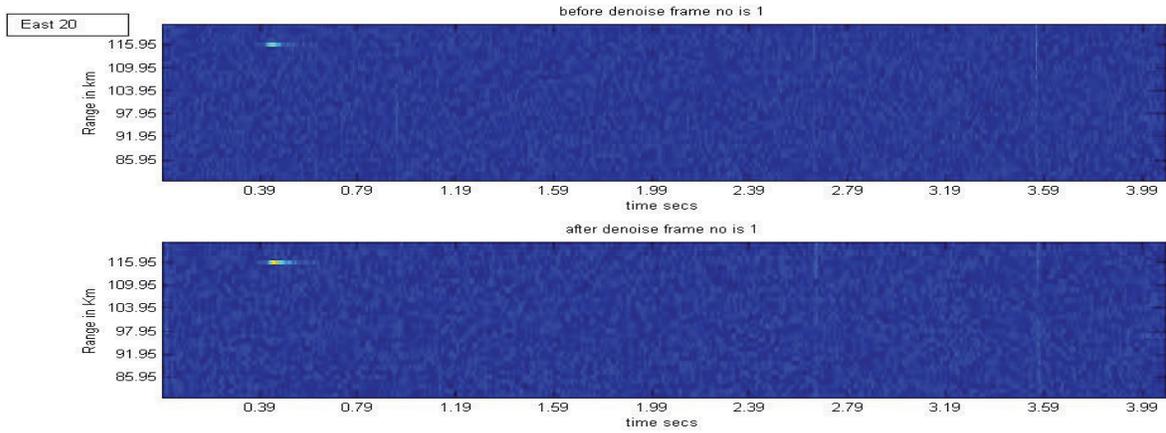


Fig.2 Meteor @ 17th November 2011 – 1st frame

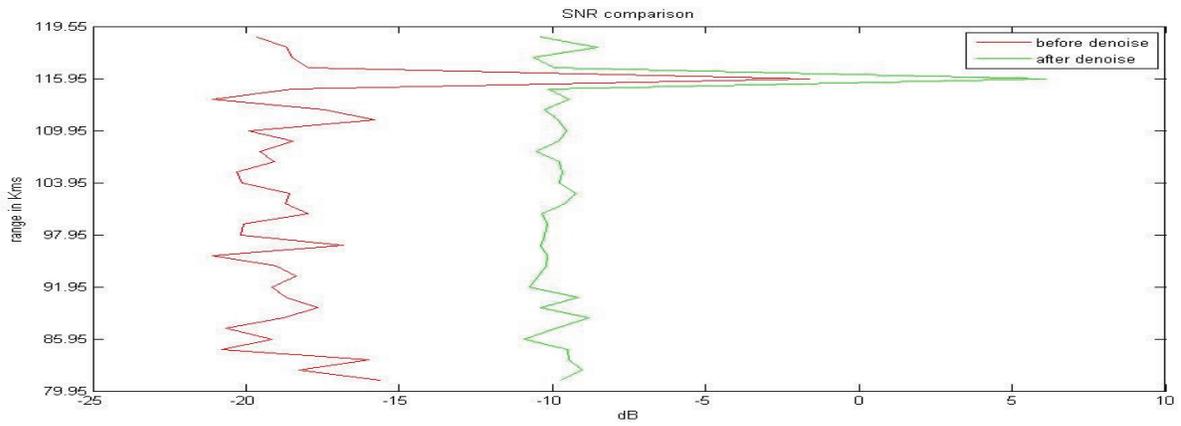


Fig.3 SNR Comparison of 17th November 2011 – 1st frame

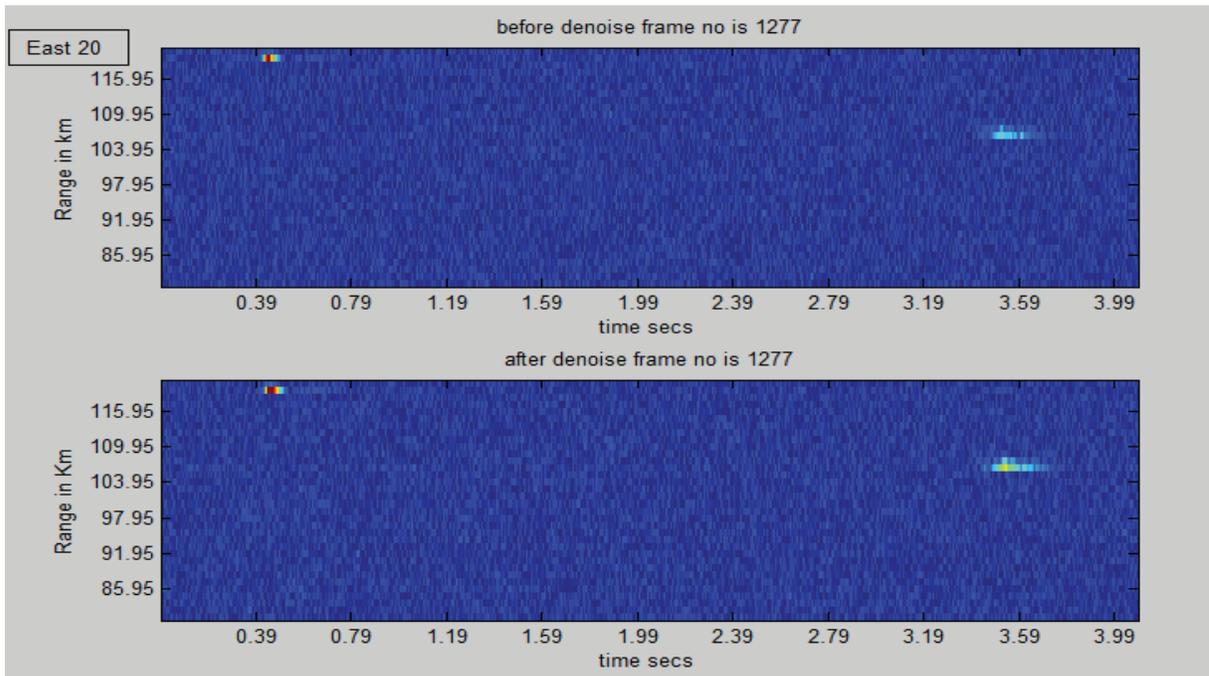


Fig.4 Meteor @ 18th November 2011 – 1277th frame

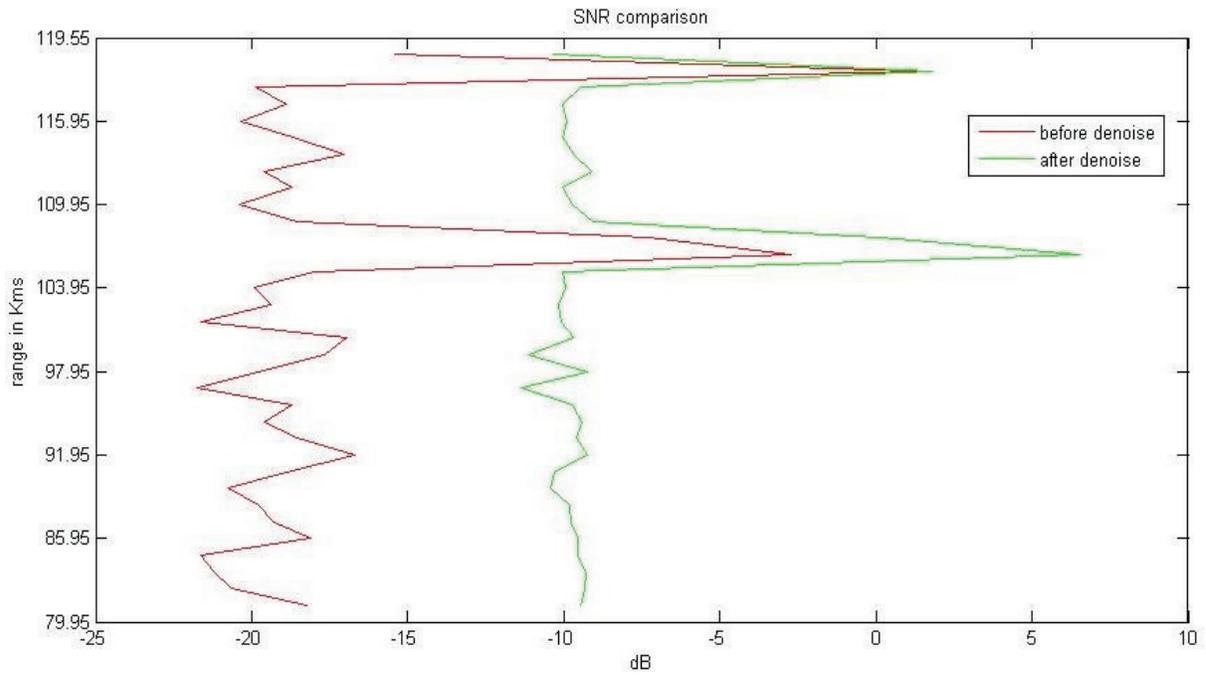


Fig.5 SNR Comparison of 18th November 2011 - 1277th frame

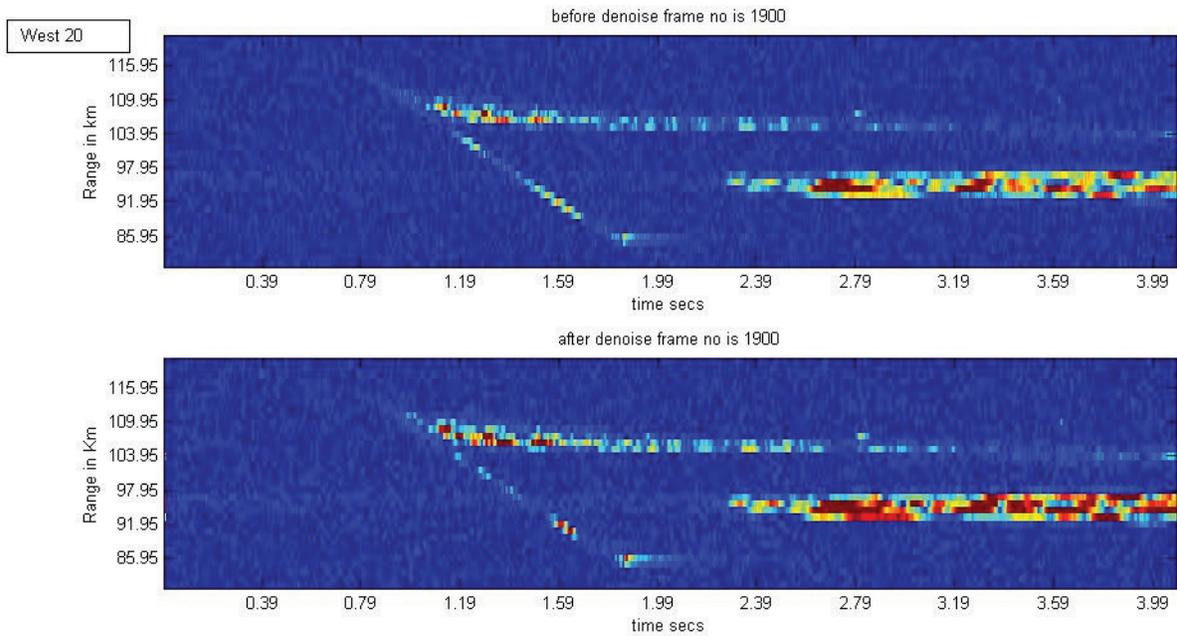


Fig.6 Meteor @ 18th November 2011 - 1900th frame

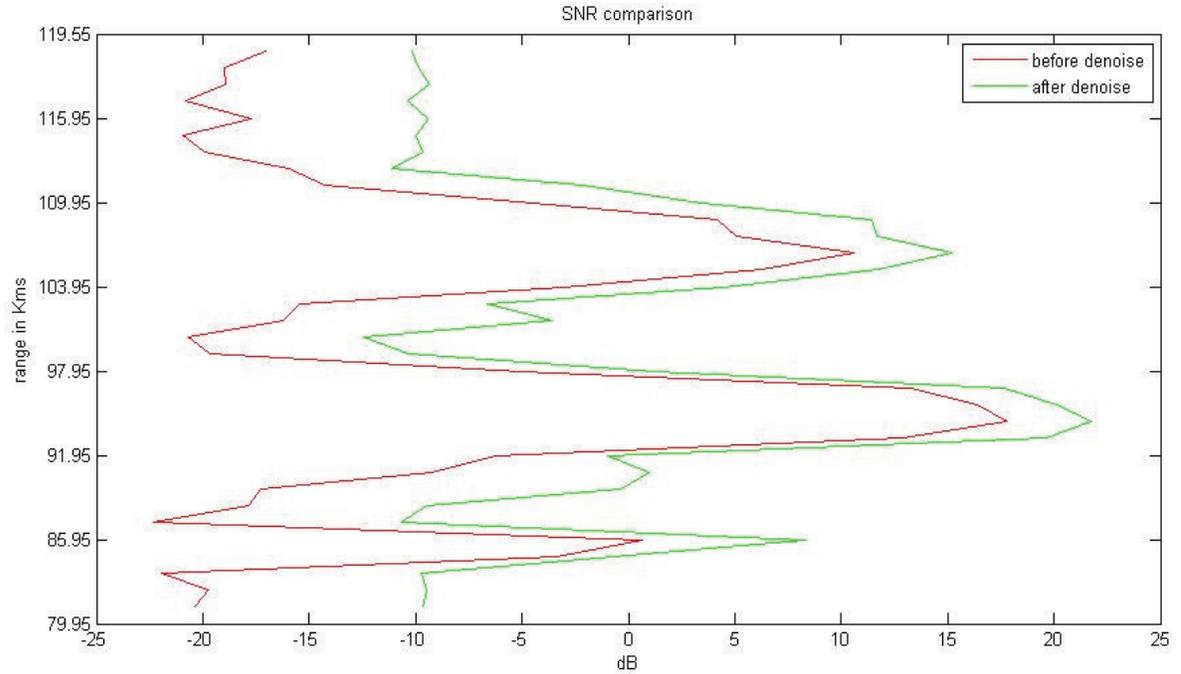


Fig.7 SNR Comparison of 18th November 2011 - 1900th frame

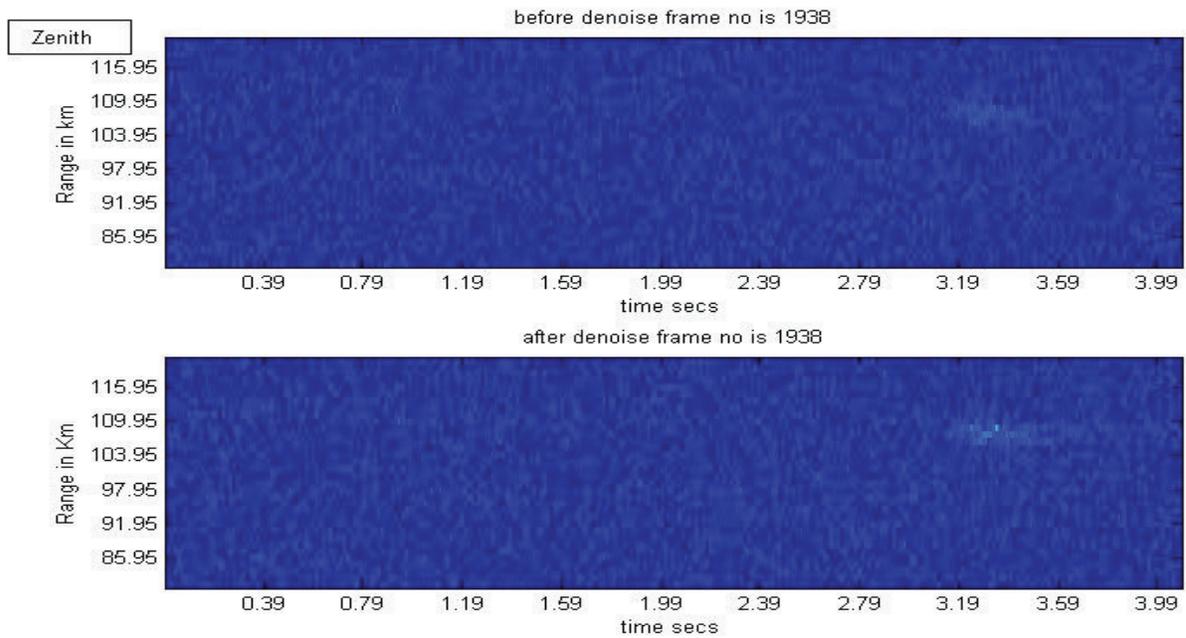


Fig.8 Meteor @ 18th November 2011 - 1938th frame

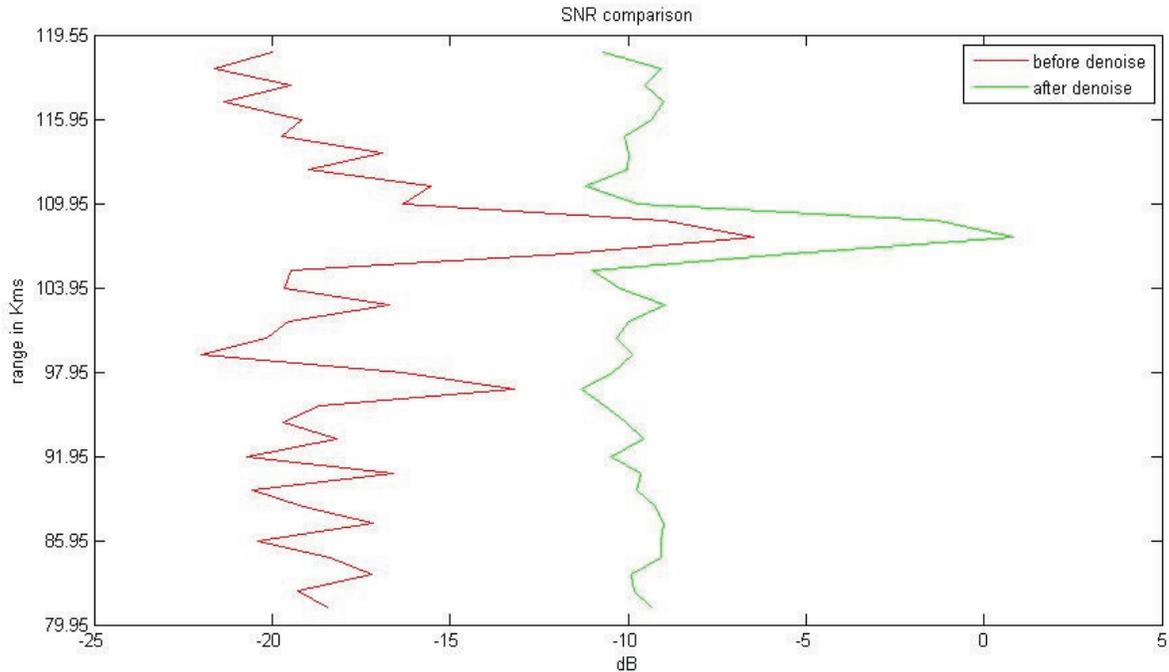


Fig.9 Meteor @ 18th November 2011 - 1938th frame

During Leonid Meteor Showers period, the meteor echoes were found to be very frequent in time and height. The Sporadic E (Es) echoes were received frequently from the northward beam, and these echoes spread over many range bins. It is also observed that more than one meteor were detected in a frame

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